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THE GREAT GRAY OWL (*STRIX NEBULOSA*) IN THE CHANGING FOREST ENVIRONMENT OF NORTHERN EUROPE

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ABSTRACT.—The Great Gray Owl (*Strix nebulosa*) breeds in northern Europe mostly in older coniferous forests. Nest sites are usually in twig nests of large hawks, sometimes on stumps, and occasionally on the ground. The availability and the quality of tree nest sites is generally lower in managed forests; however, use of artificial nests has partly compensated for declines in natural nest sites. The Great Gray Owl has increased in abundance in northern Europe over the last 30 yr. It was absent almost entirely from Finland from 1940–60, having been numerous there, especially from 1880–1910. It feeds mainly on field voles (*Microtus agrestis*), which are abundant in fields and grassy areas following forest clear-cuts. The area of clear-cuts has increased since 1950, providing more open hunting habitat and vole resources. Also, protection of all owls and increasing positive attitude toward birds of prey has coincided with the Great Gray Owl increases since the late 1960s. Forest management practices that may benefit the Great Gray Owl include shape of cuts which should be irregular and not broader than 400 m. Perch trees left in cut areas would expand the hunting area from the forest edge.

KEY WORDS: Strix nebulosa; *Great Gray Owl; trends in distribution; breeding; diet; effects of forestry.*

El Gran Búho Gris *Strix nebulosa* en cambios del ambiente en los bosques de Norte Europa

RESUMEN.—El Gran Búho Gris *Strix nebulosa* se cría en el norte de Europa mas frecuente en bosques coniferos maduros. mas viejos. Sitios de nidos están muchas veces en nidos de ramita de halcones grandes, a veces en tocones, y de vez en cuando en el terreno. La disponibilidad y la calidad de árboles con nido es generalmente mas bajo en bosques manejados. Sin embargo, uso de nidos artificiales ha compensado un poco en la reducción de nidos natural. El Gran Búho Gris ha aumentado en abundancia en el norte de Europa sobre los últimos 30 años. Estuvo ausente casi completamente en Finlandia de 1940–1960, viendo sido numeroso allí, especialmente de 1880–1910. Se alimenta principalmente con ratones de labor *Microtus agrestis,* que son abundante en los labores y áreas pastosas después de cortes-completos de bosques. El área de cortes-completos ha aumentado desde 1950, proporcionando mas hábitat abierto para cazar y recursos de *Microtus agrestis.* También, protección de todos los búhos y aumentando el actitud positivo para los ave de rapiña ha coincidido con el aumento del Gran Búho Gris desde el fin de los 1960s. Costumbres del administración de bosques que puede dar beneficio al Gran Búho Gris incluye la forma de los cortes que deben ser irregular y no mas amplio que 400 m. Árboles de percha dejados pueden aumentar áreas de cazar de la orilla del bosque.

[Traducción de Raúl De La Garza, Jr.]

A number of raptor populations have declined during the past 50 yr (e.g., the Peregrine Falcon, *Falco peregrinus,* and the Osprey, *Pandion haliaetus*), largely due to pesticides. Many forest species, such as nonmigratory owls, have not experienced similar declines, but have been affected by rapid changes in forest structure caused by forestry practices.

Public attitudes toward raptors, especially owls, have improved in recent times. Killing by hunters is now rare in the northern countries of Europe. In addition, ornithologists have prepared many nest boxes and other nesting structures for several species of owls. In Finland during 1994, 22 691 owl nest boxes were checked for occupancy (Saurola 1995).

The purpose of this paper is to review existing knowledge on the distribution and ecology of the Great Gray Owl in northern Europe and to discuss possible effects of forestry. The main topics cov-

ered are: changes in distribution, population size, causes of mortality, nest sites, diet and the possible effects of forestry.

NESTING AND FEEDING ECOLOGY

Nesting Habitats. The nesting-habitat requirements of the Great Gray Owl are fairly flexible, but most nests are found in older spruce-dominated coniferous or mixed forests. Great Gray Owls do not build their own nest structures. Nest location is, therefore, determined by nest-site requirements of large hawks, which build twig nests. Older forests may be preferred because the Northern Goshawk (*Accipiter gentilis*), the main nest-site producer, prefers this nesting habitat. The Great Gray Owl also nests in pure deciduous and pine forests. Nests in structures other than twig nests have in a few cases been in open habitats (e.g., almost open clear-cut area or open field).

Nest location is often near an opening such as a natural open bog, a clear-cut area or a small field (Pulliainen and Loisa 1977, Mikkola 1983, Hildén and Solonen 1987). When nests are 50–100 m from forest edges, the Great Gray Owl often perches at the forest edge. The most commonly used perch trees are often near the edge. Nests located in more exposed environments have shelter available nearby and young leave the nest relatively early to avoid direct sunlight (Helo 1984).

Nest Sites. Forest-management practices have decreased natural nest sites available for many large forest owls, including large stumps and holes, the former of which are used by the Great Gray Owl (Table 1). Natural twig nest sites used by the Great Gray Owl are mainly old goshawk or buzzard (*Buteo* spp.) nests, both occupied and abandoned. Nests on top of stumps (1–5 m in height) have been found in Finland, Sweden (Stefansson 1979) and Alaska (Osborne 1987). The Great Gray Owl also occupies artificial nest structures, either open boxes or platforms (Table 1). Use of artificial nests indicates a lack of natural nest sites, as in the case of the Kemi-Tornio area, but also indicates an ability to use a wide variety of nest sites and structures.

Stump nests are more common in southern areas (Hildén and Solonen 1987, Osborne 1987). This is observed to some extent in Finland, but more clearly in the U.S., where only stump nests were used in most southerly areas (Osborne 1987). Imprinting on nest structures by young (Hildén and Solonen 1987) and lack of large stumps in northern areas (Osborne 1987) are possible explanations. In addition, because owls avoid long periods of exposure to sunlight (Osborne 1987), nests on low stumps may offer more shade, which is likely more important in southern areas. Many stump nests in Finland have been found in relatively warm springs (Mikkola 1983), but correlations with temperature need further investigation. Ground nests, which have been recorded several times in Finland (Table 1), may be a response to forests with no twig or stump nest sites or they may be a response to microclimatic factors.

Table 1. Nest-site distribution (%) of the Great Gray Owl in three areas: all of Finland, western Finland and northeast of the northern Bothnian Bay (Kemi-Tornio area).

Nest Sites	All of Finland[a] %	Western Finland[b] %	Kemi-Tornio Area[c] %
Hawk twig nest	72.7	88.9	42.6
Corvid nest	4.8	1.0	3.8
Other twig nest	4.4	—	0.8
Man-made twig nest	3.6	2.0	37.2
Man-made platform or open box	—	3.0	9.3
Stump	10.8	2.0	5.4
Ground	2.4	2.0	0.8
Cliff, stone, ant hill	0.8	1.0	—
Barn roof	0.4	—	—
Number of nestings	249	99	129

[a] Hildén and Solonen 1987.
[b] K. Huhtala unpubl. data, not included in "All of Finland."
[c] Liehu et al. 1995.

Nesting Density. Nests were usually some distance apart. Saurola (1985) estimated a mean of 1 pair/100 km^2 for Finland. In several cases, however, two or more nests have been reported only 100–400 m apart (Mikkola 1981, 1983). Some group nestings are likely due to local abundance of field voles. In some other cases, old "goshawk forests" with several good alternative twig nests were the reason why two nests were situated only 100–200 m from each other. In some cases, male Great Gray Owls have been polygamous with the second female laying about 1 wk later than the first. Also, two pairs have nested only 100–300 m apart (Höglund and Lansgren 1968, Mikkola 1983) to use goshawk nests which were situated in groups in older forests.

Table 2. Composition of Great Gray Owl diet in northern Europe (%).

	SWEDEN 1955–64[a]	NORTHERN EUROPE 1955–74[b]	WESTERN FINLAND 1966–89[c]	WESTERN FINLAND 1973[d]	KOLA PENINSULA[e]
Field vole, *Microtus agrestis*	54.3	66.2	73.3	42.6	1.5
M. oeconomus and *M.* spp.	17.6	7.3	—	—	—
Bank vole, *Clethrionomys glareolus*	7.7	10.3	9.6	11.0	0.8
Grey-sided vole, *C. rufocanus*	1.5	2.9	—	—	93.8
Clethrionomys spp.	8.4	3.2	—	—	—
Water vole, *Arvicola terrestris*	1.5	1.7	4.3	1.0	—
Wood lemming, *Myopus schisticolor*	2.8	1.8	1.3	—	—
Common shrew, *Sorex araneus*	2.3	2.8	7.4	36.3	—
Soricidae spp.	2.5	1.7	2.2	2.3	0.8
Birds, Aves	0.8	1.0	0.6	0.8	—
Frogs, Amphibia	0.2	0.5	0.1	1.0	—
Other animals	—	0.4	2.1	5.0	3.1
No. items identified	1977	5177	4858	830	130

[a] Höglund and Lansgren 1968.
[b] Mikkola 1983.
[c] K. Huhtala unpubl. data.
[d] K. Huhtala unpubl. data.
[e] From Mikkola 1983.

Hunting Habitats and Diet in Northern Europe. There are numerous observations of Great Gray Owls hunting in open habitats in Finland, but quantitative data are lacking. They may fly over open terrain like Short-eared Owls (*Asio flammeus*), but most observations have been of perching birds on trees, bushes or telephone poles at or near the edges of forests (Wahlstedt 1969, Mikkola 1981, 1983). In winter, hunting dive pits in the snow are usually <50 m from the forest edge.

The diet of the Great Gray Owl in northern Europe is mainly *Microtus* voles (*M. agrestis, M. oeconomus* in Lapland; Table 2). This specialization is surprising because of the owl's size and because there are also other numerous small mammals (*Clethrionomys* voles and *Sorex* shrews) available in its environment. Field voles (*Microtus* spp.) comprise an average of 72–74% of the diet, while 8–10% consists of bank voles (*Clethrionomys* spp.) and 5–10% of shrews. In most years other prey, such as birds, frogs and larger voles (*Arvicola* spp.) are only occasionally found in the diet. The diet of the Great Gray Owl suggests that it hunts mainly in grassy areas (fields, meadows, open bogs and clear-cut areas), where *Microtus* species are found. Although there are numerous shrews available in north European grasslands, they seem to be avoided.

A comparison with the diet of Tengmalm's Owl (*Aegolius funereus*) in the same area in western Finland (Table 3) indicates that other small mammals as well as field voles are available in the same locality. Tengmalm's Owl hunts mainly in forests, but also at forest edges and in grasslands (Korpimäki 1981, 1988). However, it preys on field voles much less and feeds more on bank voles (37–46%) and shrews (15–24%). This confirms that the Great Gray Owl hunts mostly in open habitats and prefers *Microtus*.

The preference for field voles in open habitats may be partly due to the large size of the Great Gray Owl, which may make it difficult for the species to hunt in the dense forests of central Finland. This notion is supported by results of Pulliainen and Loisa (1977) in northeastern Finnish Lapland, where most old forests are rather open. There, *Microtus* and *Clethrionomys* voles are represented in the diet of the Great Gray Owl in the same percentages as are found from small mammal captures.

High abundance of *Microtus* voles in the species' diet may be overemphasized, because data are primarily based on its nesting diet and the species usually nests only in good *Microtus* years. Three samples of food from poorer *Microtus* years when the Great Gray Owl nested (Table 2) indicate that it is also capable of capturing other prey. Field voles, however, were still the main prey even in these exceptional samples from 1973–77. All three pairs nesting in central Ostrobothnia in 1973 fed

Table 3. Composition of Great Gray Owl and Tengmalm's Owl diet (%) in central Ostrobothnia (western Finland) in 1966, 1977 and 1989 (K. Huhtala unpubl. data).

	GREAT GRAY OWL			TENGMALM'S OWL		
	1966	1974	1989	1966	1974	1989
Field vole, *Microtus agrestis*	83.0	76.7	76.7	25.8	28.7	39.2
Bank vole, *Clethrionomys glareolus*	9.2	12.2	7.6	45.8	40.4	37.2
Wood lemming, *Myopus schisticolor*	—	1.2	2.3	—	—	6.7
Shrews, Soricidae	6.0	5.4	5.0	23.7	23.3	15.3
Birds, Aves	1.1	0.9	0.4	2.8	7.2	1.5
Other animals	—	1.4	0.4	1.9	0.4	0.2
No. items identified	283	1064	931	528	460	406

largely on shrews (33–41% of the diet compared to 1–6% of the diet in other years). Whereas the diet of great grays usually consists of only 0–2% frogs, 12% of the diet of a pair nesting on the island of Hailuoto in the Bothnian Bay in 1977 consisted of frogs. Similarly, the great gray diet consists of only 1–3% water voles but, in western Finland in 1977 it contained 8–15% water voles. More water voles were available, because Eagle Owls (*Bubo bubo*) also consumed more water voles in 1977 than normal.

DISTRIBUTION AND POPULATION TRENDS IN THIS CENTURY

In this century, the Great Gray Owl has nested in most of Finland, northern Sweden and occasionally in the far north of Norway (Mikkola 1983). It breeds rarely throughout Russian Karelia and is included in the Karelian Red Book on endangered animals (Shehter 1985). The most southwesterly breeding localities in Europe are in Belorus and Poland (Mikkola 1983).

The nesting population in northern Europe has changed considerably in the past 100 yr (Fig. 1). One hundred years ago (1880–1910), there were several good nesting years and Finnish egg collections alone contain more than 10 clutches from several years. At that time, the population bred in the northernmost coniferous forests, mainly in northern Finland and in northeastern Norway (Fig. 2).

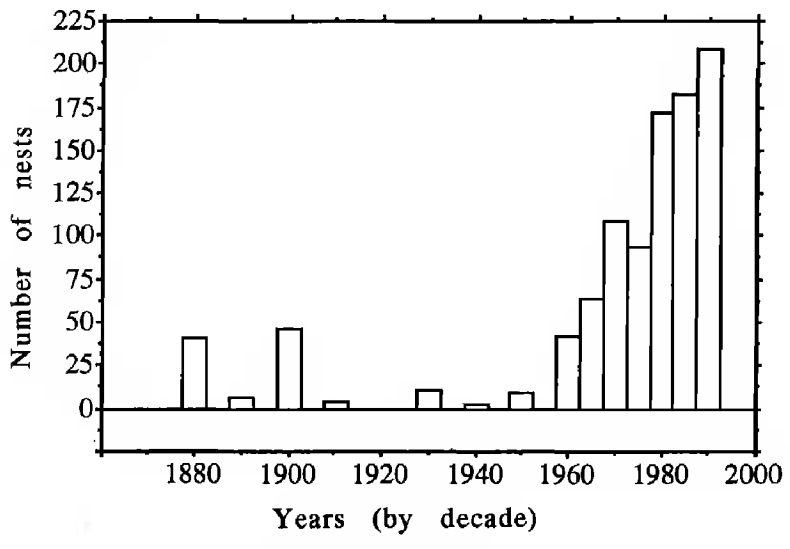

Figure 1. Number of Great Gray Owl nests found in Finland at 10-yr intervals in 1880–1960 and at 5-yr intervals in 1960–1995. Before 1940 data are from clutches in Finnish egg collections.

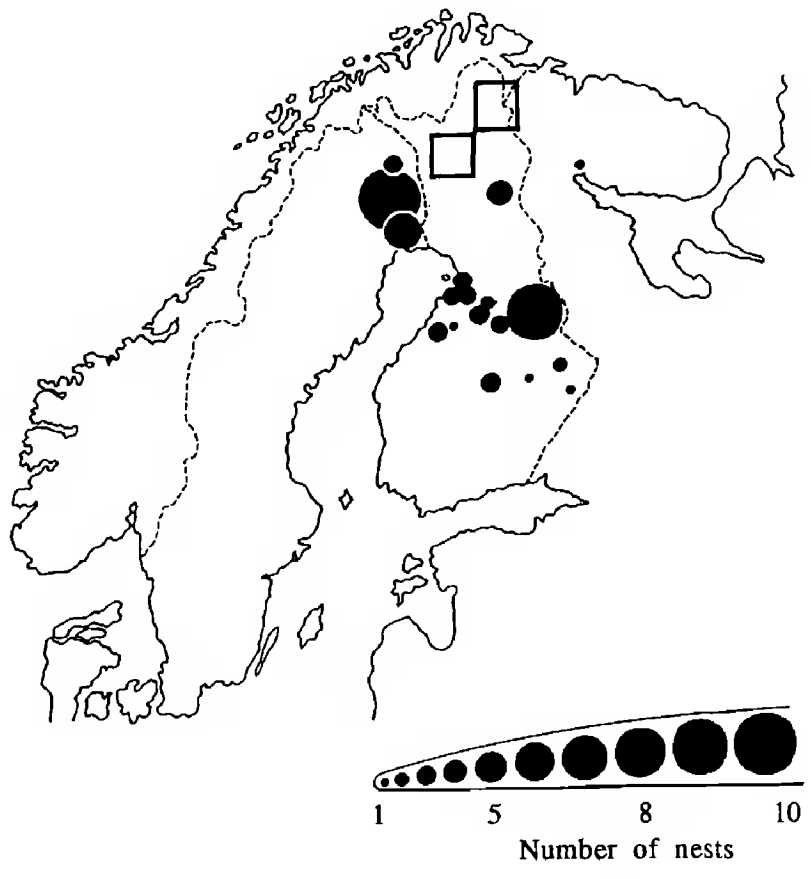

Figure 2. Distribution and relative density of Great Gray Owl nests in Finland and northern Sweden in 1955–1974 (adapted from Mikkola 1983). Squares show the main breeding areas in northern Finland and Norway in 1880–1910.

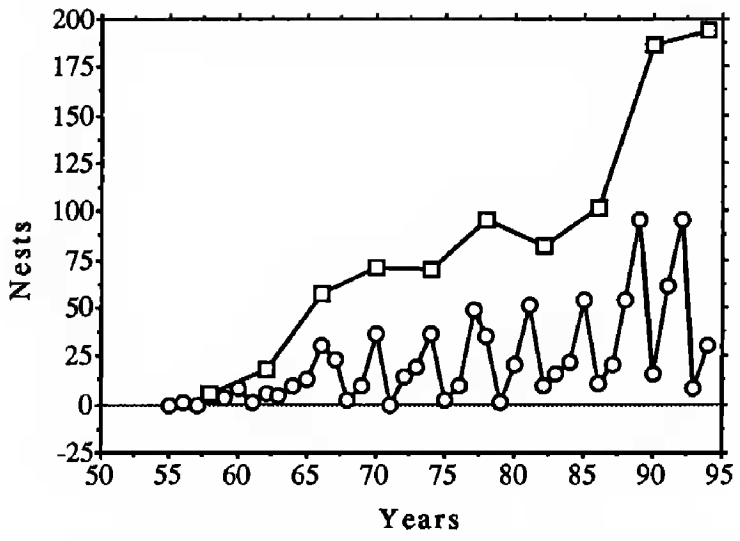

Figure 3. Number of Great Gray Owl nests found in Finland in 1955–1994, yearly (lower line) and at 4-yr periods (upper line).

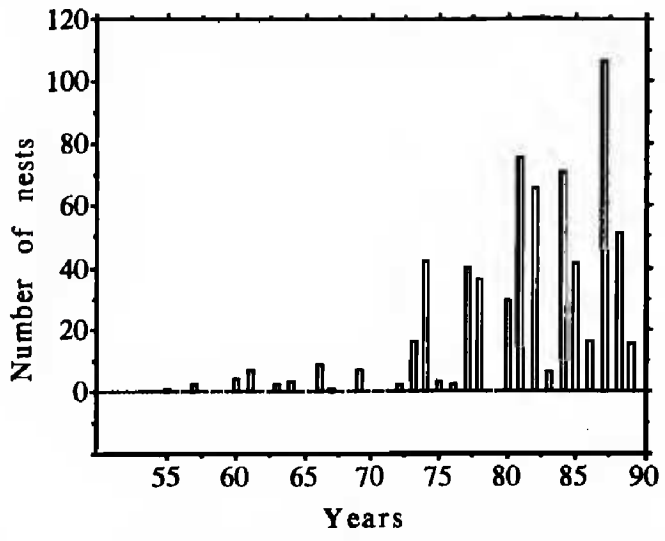

Figure 4. Number of Great Gray Owl nests recorded yearly in Sweden in 1955–1989, according to Mikkola (1983), Stefansson (1983) and Niemi (1989).

From 1910–1930, few nests were reported in Finland. Some nests were again seen during the 1930s, especially in the far north of northeastern Finnish Lapland in 1938 (Haartman et al. 1963–72, Fig. 1). Breeding Great Gray Owls were then almost absent from Finland for about 10 yr from 1940–1950. A few nests were found in the 1950s farther south, in central Finland (Merikallio 1958, Mikkola and Sulkava 1969, Hildén and Helo 1981). Few nests were found during this period in Sweden (Curry-Lindahl 1961).

There have been several winter invasions of Great Gray Owls in south and central Finland, south of the normal breeding area. However, only occasional nestings occurred in spring following invasions. Invasion years were 1895–1896, 1907–1908, 1911–1913, 1935, 1949 and 1955 (Merikallio 1958, Haartman et al. 1963–1972).

The number of nests found has increased in Finland since the 1960s (Fig. 3). Regular breeding was reestablished in Finland in 1966–1967, and since then Great Gray Owls have been nesting in the two best years of every 4-yr vole cycle (Fig. 3). In Sweden, nesting was rare until 1973 and has increased since then (Fig. 4).

There has been a steady increase in number of nests found in Finland over the last 25 yr, especially in the last 10 yr (Fig. 3). There was a slight reduction in number of nests in the 1980s compared to the number found afterward. The 4-yr vole cycle, regular since the 1950s, became irregular in the early 1980s (Henttonen et al. 1987). Consequently, the field vole peaks were not high enough to allow all Great Gray Owls to breed.

The reported increase in the number of nests found in northern Europe in 1960–1994 was partially due to the increase in nest searching for all owls for ringing (banding) and monitoring (Saurola 1986) and for building of artificial nests (Table 1). No increase in the Finnish Great Gray Owl population was determined from 1966–1984 by Saurola (1985), but since then the numbers have been higher (Fig. 3). An increase in the Great Gray Owl population is also mentioned in other studies (Mikkola 1983, Helo 1984, Solonen 1986).

The breeding area of the Great Gray Owl after 1960 has been concentrated in central and southeastern Finland, 300–500 km south of the main area of breeding before 1940 (Mikkola and Sulkava 1969, Hildén and Helo 1981, Fig. 2). The main breeding area now is in the Oulu district and since 1980 also in the Kemi-Tornio area (Solonen 1986). Because extensive cutting in Lapland began 20–40 yr later, this move from Lapland to central Finland was not caused by forestry. After this range shift, clutch size was smaller ($\bar{x} = 4.30$, SE = 0.10, $N = 70$) than in 1880–1910 ($\bar{x} = 4.63$, SE = 0.12, $N = 80$; $t = 2.16$, $P < 0.05$). However, this potential decrease in offspring production has not affected an increase in the population in recent times.

Effects of Forestry Practices

Effects of forest-management practices on owls vary, depending on the practices and the needs of the owl. Forest owls may lose nesting habitats and nest sites, but hunting for prey may be easier in cut areas. No numerical data are available on the effects of forestry on Great Gray Owls or their population in Finland. However, possible influences may be determined from indirect data on food

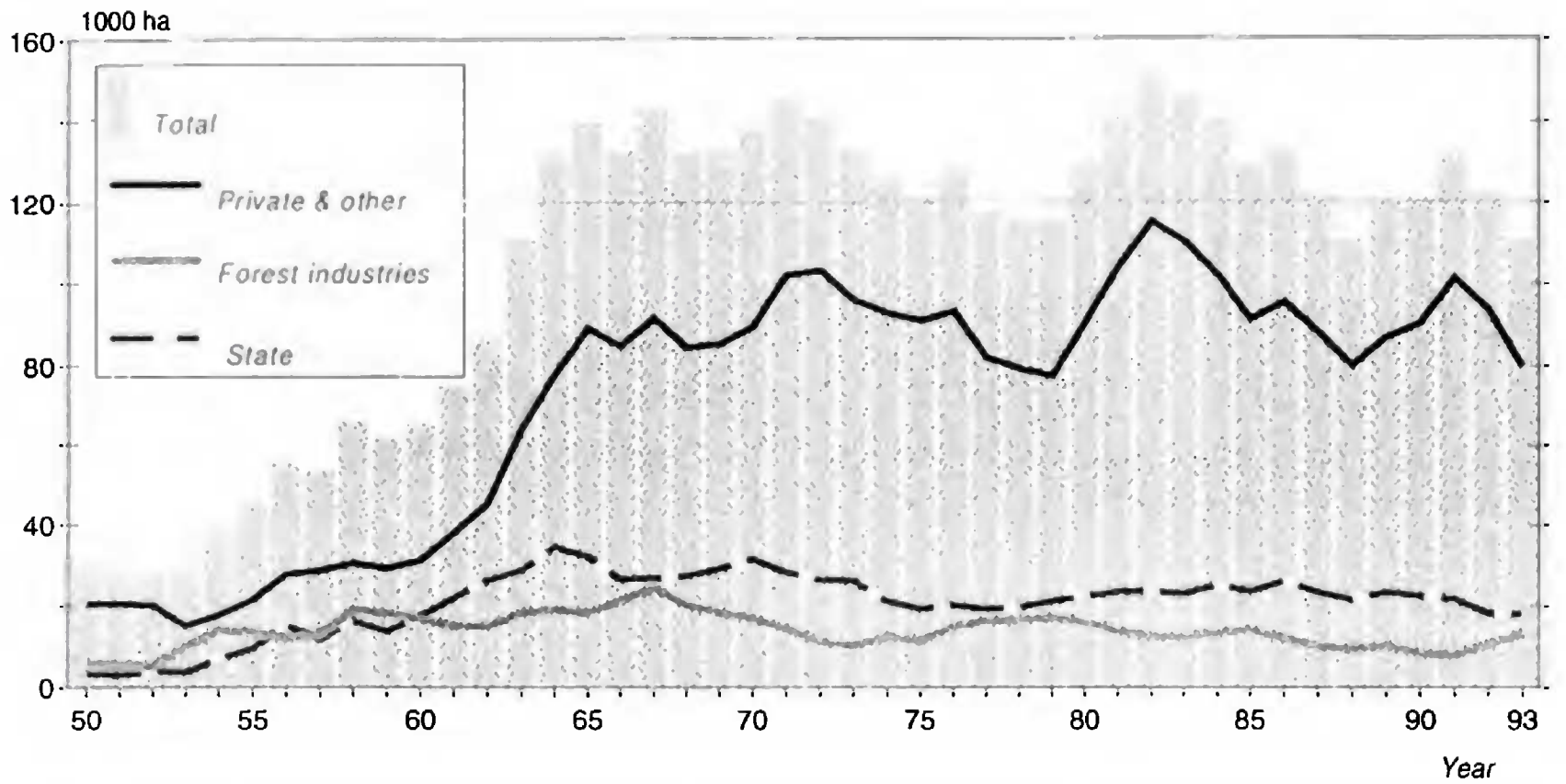

Figure 5. Area of clear-cut forest seeded or planted in Finland in 1950–1993 (total and by forest ownership category) (from Aarne 1994).

habits, changes in the environment, and from miscellaneous direct observations.

Forestry Practices in Finland, 1950–1990. The "modern and efficient" logging of forests began in northern Europe about 1950. Until that time, timber was harvested mostly by thinning the forests. Since then, forests have changed rapidly in many ways that may affect the Great Gray Owl. First, the area of old forests has rapidly decreased resulting in a decrease in large trees, in which diurnal birds of prey build their twig nests. Second, dead and broken trees have been removed resulting in a reduction in stump nest sites. Third, clear-cut areas have increased (Fig. 5) resulting in an increase in field vole production and an increase in food. Fourth, the area of young, dense forests has increased, decreasing the area available for hunting or nesting. Fifth, the area of drained wet bogs has increased, leading to a decrease in the area available for field vole production. Sixth, roads are being built in remote forest areas leading to increased disturbance (Fig. 7).

Nesting Habitat Availability. Large areas of clear-cutting (several km^2 at a time) indicate that the Great Gray Owl has lost considerable breeding habitat, which may reduce local breeding populations. It may be argued that, because of the species' flexibility in nest habitat use, it will have adequate forests for breeding in northern Europe in the future. The availability of nesting habitat may not be a limiting factor, although it is not known how large a forest a nesting pair of Great Gray Owls needs between cut areas.

Decline in Availability and Quality of Nesting Sites. The Great Gray Owl nests in a variety of structures (Table 1), but large twig nests and stumps are the main natural sites used. The numbers of these nest sites have decreased because of forestry practices for several reasons. First, the area of older forests that contain hawk nests has decreased because of clear-cutting. Second, the number of stump nest sites in forests has decreased because dead and broken trees have been removed in the course of forest management. Third, the number of alternative nests per hawk pair is probably smaller in young forests. Young trees have weaker branches and, consequently, nests collapse more often. In addition, poor quality of twig nests in young forests may lead to nest failures, but the extent of such losses is unknown.

The number of twig nest sites currently available seems to be sufficient in Finland. Solonen (1986) estimated that there were about 50 000 twig nests available in Finland in 1986, and even if 50% of these were outside the normal breeding area of the Great Gray Owl, the number would still probably suffice for the estimated 500–1500 Great Gray Owl pairs in the country. In addition, populations of

large hawks, goshawks, Honey-buzzards (*Pernis apivorus*) and buzzards (*Buteo* spp.) have been stable in Finland in recent times (Saurola 1985, Haapala et al. 1995). These species will likely produce enough new twig nests for Great Gray Owl use in the future, too, despite the fact that hawk nests are sometimes destroyed by the Great Gray Owl when it digs out the nest bowl. In the first digging phase in early spring, the owl often digs a 10–15 cm deep bowl. This perhaps dries the nest material; the final bowl for the eggs is only about 6 cm deep. Rapid wear of hawk nests used by Great Gray Owls has also been observed by Stefansson (1979) in Sweden.

The readiness of the Great Gray Owl to use various nest structures points to a lack of suitable nesting sites. Man-made nests are often used in North America (Nero 1980, 1982, Bohm 1985, Bull et al. 1987) and, in Finland, open box nests have been used in Kainuu (Helo 1984) and central Ostrobothnia. Almost half the Great Gray Owls reported in the Kemi-Tornio area in the 1990s occupied artificial nests composed of twigs (Liehu et al. 1995, Table 1).

Increase in Hunting Habitat Availability. To find enough *Microtus* voles, the Great Gray Owl needs open habitats with grasses, herbs and sedges. These habitats include hay fields (cultivated, temporarily unused or abandoned), open wet bogs, bog margins or clear-cut forest areas. The area in hay fields has increased, especially those unused or abandoned. Only a small proportion of abandoned fields have been planted with trees. The number of clear-cut areas of different ages has increased substantially since the 1950s (Fig. 5). The vegetation on most of these areas will support field vole populations. The common practice of plowing cut areas has increased the growth of grasses. The number of wet sedge bogs has decreased due to extensive draining for forestry or peat production (Aarne 1994). Drained areas are only partly suitable for field voles.

Clear-cutting is obviously the main factor which has increased hunting habitat availability to the Great Gray Owl in forest areas since the 1950s. Before 1950, timber was removed by selective harvest, but between 1950–1994, clear-cutting was the primary logging practice. Only in the last few years has "continuous cultivation" (selective harvest) of the forest been allowed again; clear-cutting is still the main practice. Before the early 1990s, clear-cut areas were mostly carefully cleared of all timber,

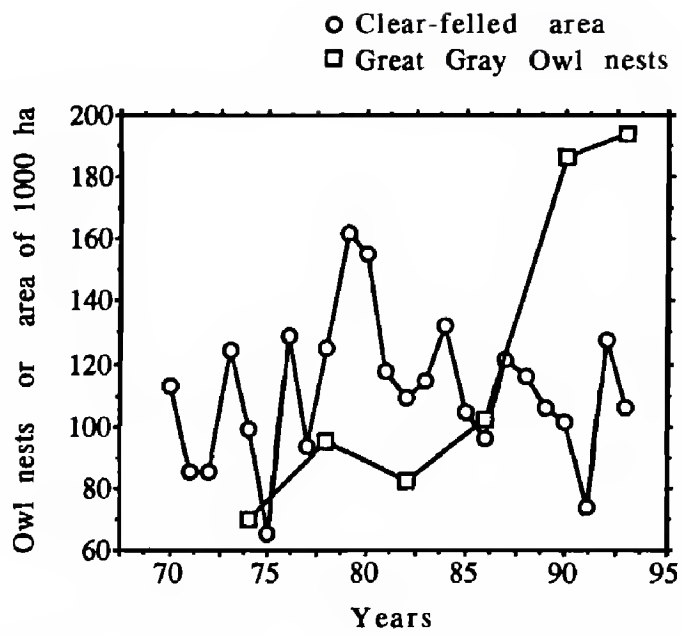

Figure 6. Total clear-cut area (in 1000 ha) in Finland from 1970–1993 (from Aarne 1994) and Great Gray Owl nests recorded at 4-yr intervals from 1970–1994.

including dead and young trees, and the land was often burned, ditched or plowed before it was seeded or planted (Fig. 5).

During the expansion of the Great Gray Owl population in Finland since the 1960s, clear-cut areas have provided more field voles for raptors than in earlier periods (Teivainen 1979). In state forests in northern Finland and in forests of timber companies in central Finland, the clearings have often been too large (more than 20 ha) and too open to be used as hunting grounds. The owls probably hunted only at the edges of these large openings.

The future may be better because new rules for forest management and cutting practices have been prepared and partly introduced in 1994–1995. Cut areas will be smaller in size (mostly not more than 5–10 ha) and groups of both live and dead trees will be left in cut areas. Also, forest strips will be left along lake shores and stream valleys.

Prey Availability. The Great Gray Owl requires a high density of voles (mostly field voles) to breed, and therefore generally breeds only in increasing and peak years of the northern vole population cycles which are more pronounced than in more southern areas of Europe (Hansson and Henttonen 1985). In the northernmost breeding areas of northern Europe (Fig. 2), *M. oeconomus* and even *C. rufocanus* may produce enough food for breeding (Table 1) because these species are often the most abundant voles in open habitats.

The increased vole resources due to clear-cuts (Teivainen 1979) have obviously been important to support the increase in Great Gray Owls in north-

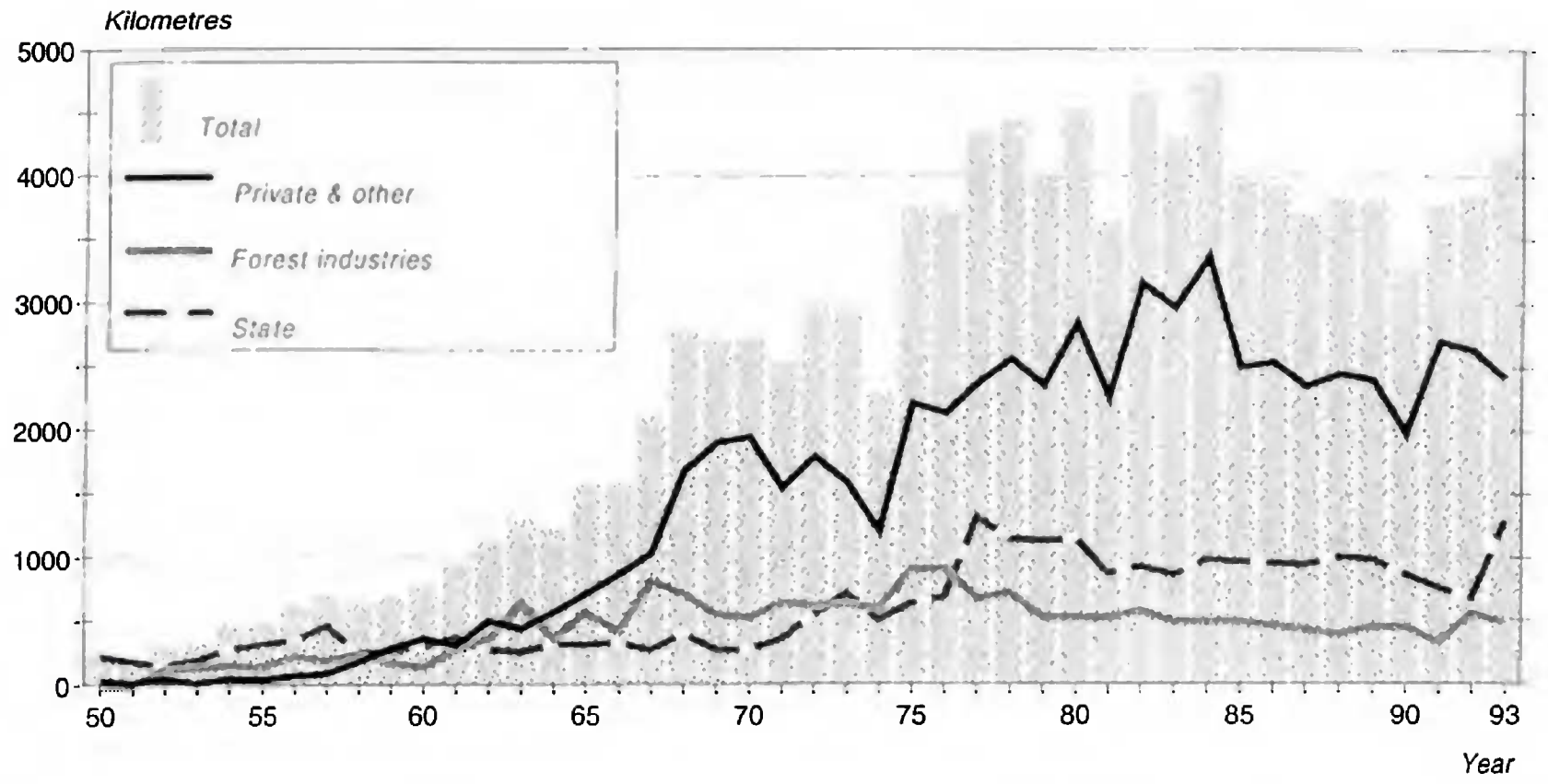

Figure 7. Permanent forest roads (in km) completed in Finland from 1950–1993 (total and by forest ownership category, from Aarne 1994).

ern Europe. In Germany, the number of breeding Tengmalm's Owls increased after extensive clear-cutting and decreased again with reforestation. This was due to the greater abundance of rodents in recently cut areas (Mebs 1987). The breeding population of Great Gray Owls seems to have grown more than what would be supported by only an increase in area of recent clear-cuts in Finland (Fig. 6). Since about 1980, the total area of clear-cuts has decreased slightly, but the number of nests of the Great Gray Owl identified has increased.

Size, Shape and Distribution of Harvested Areas. Our knowledge of the breeding and hunting requirements of the Great Gray Owl is still inadequate for precise recommendations on forestry practices. Its hunting habits in large openings and the amount of forest necessary for breeding are not sufficiently well known. The following descriptions of beneficial and detrimental forestry practices are therefore only approximate: (1) Most cuttings should be restricted to areas of 20 ha in size; cuts of 2–5 ha are probably the best size. Cut areas larger than 20 ha should be irregular in shape, not broader than 400–500 m, and with convoluted edges to give shelter when hunting at the edge. All cuts should have groups of trees left for perching. (2) Forest strips (corridors), 50–100 m wide, should be left between the cut areas for moving and sheltered resting places, and there should be some larger forest areas, 5–10 ha in size, between the cut areas to provide nesting habitat.

Most detrimental for the Great Gray Owl would be large-scale clear-cuts of more than 100 ha that are circular or square in form, especially if they are totally treeless and with only small patches of forest remaining between them. In this situation, the species would not have appropriate food resources, nesting habitats or resting and perching places.

In practice, fairly diverse cut sizes are acceptable by the Great Gray Owl as long as small groups of live and dead trees are left and forest corridors are left along shores and streams, and between large cuts.

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